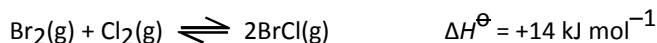


Topic 07/17 HL Review – Equilibrium (2011 Exam)

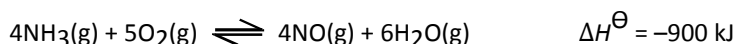
Name.....

1. What changes occur when the temperature is increased in the following reaction at equilibrium?



	Position of equilibrium	Value of equilibrium constant
A.	Shifts towards the reactants	Decreases
B.	Shifts towards the reactants	Increases
C.	Shifts towards the products	Decreases
D.	Shifts towards the products	Increases

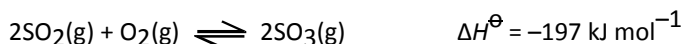
2. The equation for a reaction used in the manufacture of nitric acid is



Which changes occur when the temperature of the reaction is increased?

	Position of equilibrium	Value of K_c
A.	shifts to the left	increases
B.	shifts to the left	decreases
C.	shifts to the right	increases
D.	shifts to the right	decreases

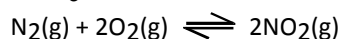
3. The manufacture of sulfur trioxide can be represented by the equation below.



What happens when a catalyst is added to an equilibrium mixture from this reaction?

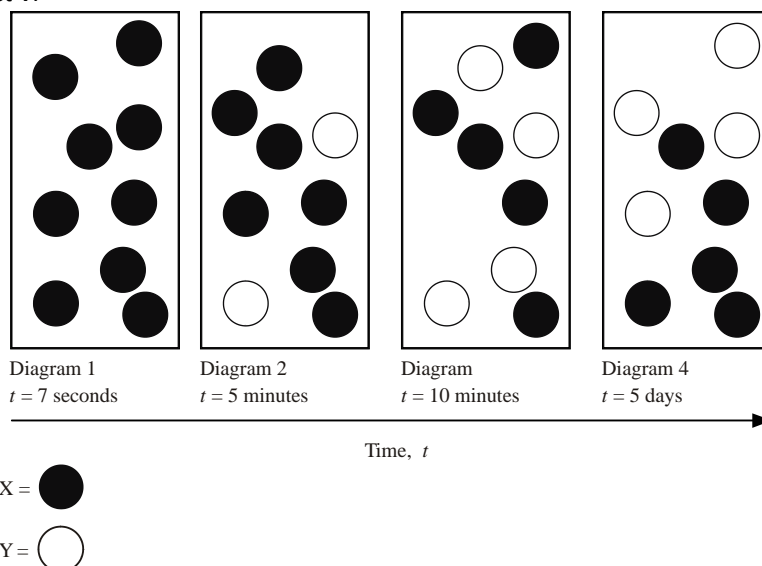
- A. The rate of the forward reaction increases and that of the reverse reaction decreases.
 B. The rates of both forward and reverse reactions increase.
 C. The value of ΔH^\ominus increases.
 D. The yield of sulfur trioxide increases.
4. The equation for the Haber process is:
- $$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H^\ominus = -92.2 \text{ kJ}$$
- Which conditions will favor the production of the greatest amount of ammonia at equilibrium?
- A. High temperature and high pressure
 B. High temperature and low pressure
 C. Low temperature and high pressure
 D. Low temperature and low pressure
5. Which statement concerning a chemical reaction at equilibrium is **not** correct?
- A. The concentrations of reactants and products remain constant.
 B. Equilibrium can be approached from both directions.
 C. The rate of the forward reaction equals the rate of the reverse reaction.
 D. All reaction stops.

6. What is the equilibrium constant expression, K_c , for the reaction below?



- A. $K_c = \frac{[\text{NO}_2]}{[\text{N}_2][\text{O}_2]}$
 B. $K_c = \frac{2[\text{NO}_2]}{3[\text{N}_2][\text{O}_2]}$
 C. $K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2][\text{O}_2]^2}$
 D. $K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2] + [\text{O}_2]^2}$

7. The sequence of diagrams represents the system as time passes for a gas phase reaction in which reactant X is converted to product Y.



Which statement is correct?

- A. At $t = 5$ days the rate of the forward reaction is greater than the rate of the backward reaction.
- B. At $t = 7$ seconds the reaction has reached completion.
- C. At $t = 10$ minutes the system has reached a state of equilibrium.
- D. At $t = 5$ days the rate of the forward reaction is less than the rate of the backward reaction.
8. Sulfur dioxide and oxygen react to form sulfur trioxide according to the equilibrium.
- $$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$$
- How is the amount of SO_3 and the value of the equilibrium constant for the reaction affected by an increase in pressure?
- A. The amount of SO_3 and the value of the equilibrium constant both increase.
- B. The amount of SO_3 and the value of the equilibrium constant both decrease.
- C. The amount of SO_3 increases but the value of the equilibrium constant decreases.
- D. The amount of SO_3 increases but the value of the equilibrium constant does not change.
9. A sealed container at room temperature is half full of water. The temperature of the container is increased and left for equilibrium to re-establish. Which statement is correct when the equilibrium is re-established at the higher temperature?
- A. The rate of vaporization is greater than the rate of condensation.
- B. The amount of water vapor is greater than the amount of liquid water.
- C. The amount of water vapor is greater than it is at the lower temperature.
- D. The rate of condensation is greater than the rate of vaporization.
10. The equation for a reversible reaction used in industry to convert methane to hydrogen is shown below.
- $$\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g}) \quad \Delta H^\ominus = +210 \text{ kJ}$$
- Which statement is always correct about this reaction when equilibrium has been reached?
- A. The concentrations of methane and carbon monoxide are equal.
- B. The rate of the forward reaction is greater than the rate of the reverse reaction.
- C. The amount of hydrogen is three times the amount of methane.
- D. The value of ΔH^\ominus for the reverse reaction is -210 kJ .
11. Which statement is always true for a chemical reaction that has reached equilibrium?
- A. The yield of product(s) is greater than 50%.
- B. The rate of the forward reaction is greater than the rate of the reverse reaction.
- C. The amounts of reactants and products do not change.
- D. Both forward and reverse reactions have stopped.

12. In the Haber process for the synthesis of ammonia, what effects does the catalyst have?

	Rate of formation of $\text{NH}_3(\text{g})$	Amount of $\text{NH}_3(\text{g})$ formed
A.	Increases	Increases
B.	Increases	Decreases
C.	Increases	No change
D.	No change	Increases

13. Which of the following equilibria would **not** be affected by pressure changes at constant temperature?

- A. $4\text{HCl}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{H}_2\text{O}(\text{g}) + 2\text{Cl}_2(\text{g})$
 B. $\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{CO}_2(\text{g})$
 C. $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(\text{g})$
 D. $\text{PF}_3\text{Cl}_2(\text{g}) \rightleftharpoons \text{PF}_3(\text{g}) + \text{Cl}_2(\text{g})$

14. $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) \quad \Delta H^\ominus = -200 \text{ kJ}$

According to the above information, what temperature and pressure conditions produce the greatest amount of SO_3 ?

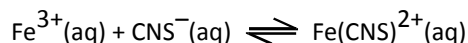
	Temperature	Pressure
A.	low	low
B.	low	high
C.	high	high
D.	high	low

15. What will happen if $\text{CO}_2(\text{g})$ is allowed to escape from the following reaction mixture at equilibrium?



- A. The pH will decrease.
 B. The pH will increase.
 C. The pH will remain constant.
 D. The pH will become zero.

16. Iron(III) ions react with thiocyanate ions as follows.



What are the units of the equilibrium constant, K_c , for the reaction?

- A. mol dm^{-3}
 B. $\text{mol}^2 \text{dm}^{-6}$
 C. $\text{mol}^{-1} \text{dm}^3$
 D. $\text{mol}^{-2} \text{dm}^6$

17. Which statements are correct for a reaction at equilibrium?

- I. The forward and reverse reactions both continue.
 II. The rates of the forward and reverse reactions are equal.
 III. The concentrations of reactants and products are equal.

- A. I and II only
 B. I and III only
 C. II and III only
 D. I, II and III

18. Which statement(s) is/are true for a mixture of ice and water at equilibrium?

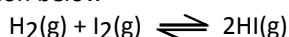
- I. The rates of melting and freezing are equal.
 II. The amounts of ice and water are equal.
 III. The same position of equilibrium can be reached by cooling water and heating ice.

- A. I only
 B. I and III only
 C. II only
 D. III only

19. The rate of a reversible reaction is altered by the addition of a heterogeneous catalyst. Which statement correctly describes the role of the catalyst?
- It alters the enthalpy change of the reaction.
 - It decreases the activation energy of the forward reaction.
 - It increases the activation energy of the reverse reaction.
 - It increases the rate of the forward reaction but decreases the rate of the reverse reaction.
20. A liquid and its vapor are at equilibrium inside a sealed container. Which change would alter the equilibrium vapor pressure of the liquid in the container?
- Adding more liquid
 - Adding more vapor
 - Decreasing the volume of the container
 - Decreasing the temperature

HL Questions:

21. For the reaction below

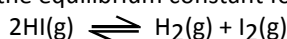


at a certain temperature, the equilibrium concentrations are (in mol dm^{-3})

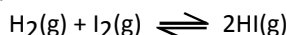
$$[\text{H}_2] = 0.30, [\text{I}_2] = 0.30, [\text{HI}] = 3.0$$

What is the value of K ?

- 5.0
 - 10
 - 15
 - 100
22. The value of the equilibrium constant for the reaction



is 0.25 at 440°C . What would the value of the equilibrium constant be for the following reaction at the same temperature?



- 0.25
 - 0.50
 - 2.0
 - 4.0
23. Hydrogen and carbon dioxide react as shown in the equation below.



For this reaction the values of K_c with different temperatures are

Temperature / K	K_c
500	7.76×10^{-3}
700	1.23×10^{-1}
900	6.01×10^{-1}

Which statement for the reaction is correct?

- The forward reaction is endothermic.
- $\text{H}_2\text{O}(\text{g})$ and $\text{CO}(\text{g})$ are more stable than $\text{H}_2(\text{g})$ and $\text{CO}_2(\text{g})$.
- The reaction goes almost to completion at high temperatures.
- The reverse reaction is favored by high temperatures.

24. The expression for the equilibrium constant for a reaction is

$$K_c = \frac{[\text{B}][\text{C}]}{[\text{A}]^2}$$

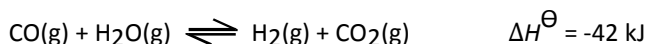
At a certain temperature the values of $[\text{A}]$, $[\text{B}]$ and $[\text{C}]$ are all 0.2 mol dm^{-3} . What happens to the value of K_c when all three values are doubled to 0.4 mol dm^{-3} ?

- It is halved.
- It does not change.
- It doubles.
- It increases by a factor of four.

25. A 1.0 dm^3 reaction vessel initially contains 6.0 mol of **P** and 6.0 mol of **Q**. At equilibrium 4.0 mol of **R** is present. What is the value of K_c for the following reaction?



- A. 0.11
B. 0.25
C. 0.44
D. 4.00
26. For the reaction below:
- $$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$$
- at a certain temperature, the equilibrium concentrations, in mol dm^{-3} , are
 $[\text{H}_2(\text{g})] = 0.30$, $[\text{I}_2(\text{g})] = 0.30$, $[\text{HI}(\text{g})] = 3.0$
What is the value of K ?
- A. 1.0×10^{-2}
B. 10
C. 33
D. 1.0×10^2
27. A liquid and its vapor are at equilibrium inside a sealed container. Which change will alter the equilibrium vapor pressure of the liquid in the container?
- A. Adding more liquid
B. Adding more vapor
C. Decreasing the volume of the container
D. Decreasing the temperature
28. The equation for another reaction used in industry is



- (i) Under certain conditions of temperature and pressure, 2.0 mol of carbon monoxide and 3.2 mol of steam were left to reach equilibrium. At equilibrium, 1.6 mol of both hydrogen and carbon dioxide were present. Calculate the amounts of carbon monoxide and steam at equilibrium and the value of K_c .

(3)

- (ii) Under the same conditions of temperature and pressure, 2.0 mol of carbon monoxide and 2.0 mol of steam were left to reach equilibrium. Calculate the amounts of each reactant and product at equilibrium.
(If you were unable to calculate a value for K_c in (i) use the value 9.0, although this is not the correct value.)

(2)

(Total 5 marks)

29. The equilibrium between nitrogen dioxide (dark brown) and dinitrogen tetroxide (colorless) is represented by the following equation.

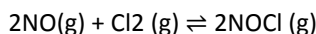


State and explain the visible change that takes place as a result of a decrease in pressure, after equilibrium is re-established.

.....
.....
.....
.....

(Total 2 marks)

30. Consider the following reaction studied at 263 K.



- a) It was found that the forward reaction is first order with respect to Cl_2 and second order with respect to NO . The reverse reaction is second order with respect to NOCl .

i) State the rate expression for the forward reaction.

[1]

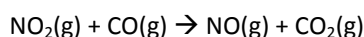
ii) Predict the effect on the rate of the forward reaction and on the rate constant if the concentration of NO is halved.

[2]

iii) 1.0 mol of Cl_2 and 1.0 mol of NO are mixed in a closed container at constant temperature. Sketch a graph to show how the concentration of NO and NOCl change with time until after equilibrium has been reached. Identify the point on the graph where equilibrium is established.

[4]

- b) Consider the following reaction.



Possible reaction mechanisms are:

– Above 775 K: $\text{NO}_2 + \text{CO} \rightarrow \text{NO} + \text{CO}_2$ *slow*

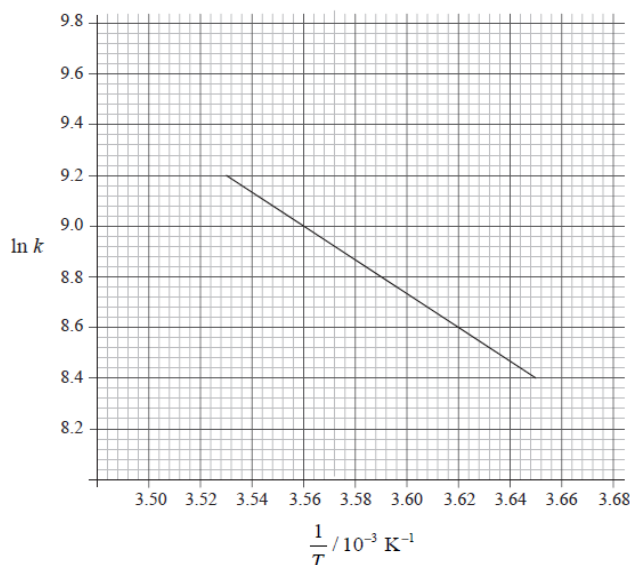
– Below 775 K: $2\text{NO}_2 \rightarrow \text{NO} + \text{NO}_3$ *slow*
 $\text{NO}_3 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$ *fast*

Based on the mechanisms, deduce the rate expressions above and below 775 K.

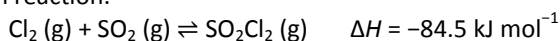
[2]

- c) State **two** situations when the rate of a chemical reaction is equal to the rate constant. [Normally 2, only worth 1]

- d) Consider the following graph of $\ln k$ against $1/T$ for the first order decomposition of N_2O_4 into NO_2 . Determine the activation energy in kJ mol^{-1} for this reaction. **[Normally 2, only worth 1]**



- e) Consider the following equilibrium reaction.



In a 1.00 dm^3 closed container, at 375°C , $8.60 \times 10^{-3} \text{ mol}$ of SO_2 and $8.60 \times 10^{-3} \text{ mol}$ of Cl_2 were introduced. At equilibrium, $7.65 \times 10^{-4} \text{ mol}$ of SO_2Cl_2 was formed.

- i) Deduce the equilibrium constant expression, K_c , for the reaction. **[1]**

- ii) Determine the value of the equilibrium constant, K_c . **[3]**

- iii) If the temperature of the reaction is changed to 300°C , predict, stating a reason in each case, whether the equilibrium concentration of SO_2Cl_2 and the value of K_c will increase or decrease. **[3]**

- iv) If the volume of the container is changed to 1.50 dm^3 , predict, stating a reason in each case, how this will affect the equilibrium concentration of SO_2Cl_2 and the value of K_c . **[3]**

- v) Suggest, stating a reason, how the addition of a catalyst at constant pressure and temperature will affect the equilibrium concentration of SO_2Cl_2 . **[2]**

[Normally 25, Total 23 marks]